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This issue contains articles on the following subjects: 1.Computer-Aided Systems Human Engineering: A Hypermedia Tool; 2.Virtual Ecology of Work and System Design; 3.IDEA: The HSI/HFE Integrated Decision/Engineering Aid; 4.The Reorganization of the Armstrong Laboratory Human Engineering Division; 5.Liveware Survey of Human Systems Integration (HSI) Tools;

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VOLUME III: NUMBER 2, MARCH/APRIL 1992

CSERIAC GATEWAY

PUBLISHED BY THE CREW SYSTEM ERGONOMICS INFORMATION ANALYSIS CENTER

In this issue:

CSERIAC is a United States Department of Defense Information Analysis Center administered by the Defense Technical Information Center, Alexandria, VA, managed by the Armstrong Laboratory, Wright-Patterson Air Force Base, OH, and operated by the University of Dayton Research Institute, Dayton, OH.

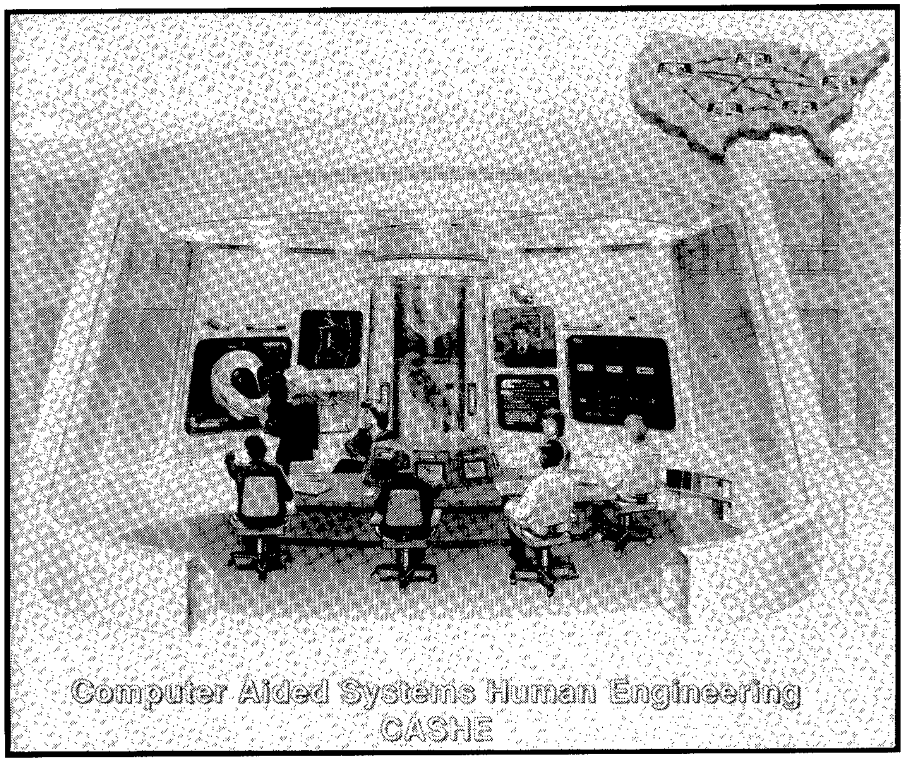


Figure 1. The CASHE " vision" is to have ergonomics data available in a computer-aided design environment.

Computer-Aided Systems Human Engineering: A Hypermedia Tool

Donald L. Monk
Kenneth R. Boff

Over a decade of prior research and development aimed at understanding and remediating problems in the transition of ergonomics data and models to application in the design of complex human-operated systems has coalesced into a new model of Computer-Aided Systems Human Engineering (CASHE). As its objective, CASHE will enable ergonomics to be fully supported as a "full partner" among other design disciplines within a computer-aided design environment, as shown in Figure 1. CASHE will offer designers of crew systems a previously nonexistent, integrated support capability that enables access and modeling of human performance and cognition within an electronic prototyping environment.

he first implementation of CASHE, the Performance Visualization Subsystem (PVS) Version 1.0; is sponsored by the Armstrong Laboratory; US Federal Aviation Administration; US Army Engineering Laboratory; Naval Command, Control, and Ocean Surveillance Center; Air Force Office of

Continued on page 2

Scientific Research; Nuclear Regulatory Commission; and NATO AGARD. CASHE-PVS Version 1.0 is derived from the work of the Human Engineering Division of the Armstrong Laboratory. The Human Engineering Division has long been involved with the research and development of crew station design technology, with special emphasis on melding the needs of the designer with the constraints of system design. The CASHE-PVS Version 1.0 is an attempt to bridge this gap by aiding designers in accessing, understanding, and applying human perception and performance data. This has been accomplished through the integration of traditional ergonomic data representation formats (e.g., text, tables, and figures) with alternative representations (e.g., audio and animations) and with specialized data visualization techniques.

System Description

Information Base

To promote learning and ease-of-use, CASHE-PVS Version 1.0 is oriented around a bookshelf metaphor to access reference documents. This takes advantage of the user's knowledge and operations with the hardcopy media on which it is based. The Bookshelf (see Fig.2) consists of:

- *Engineering Data Compendium* (Boff & Lincoln, 1988), developed through the joint efforts of the Department of Defense, NASA, and NATO AGARD as a standardized ergonomics data resource for system designers;
- *MIL-STD-1472D* (Department of Defense, 1989), a military standard for human engineering design criteria for systems, equipment, and facilities;
- Perception and Performance Prototyper (P^3), an interactive simulator that enables users to experience and explore behavioral phenomena contained in the *Compendium* and *MIL-STD-1472D*; and
- Project Files, a collection of information which the user may add to customize the system and store files and annotations created during a session.

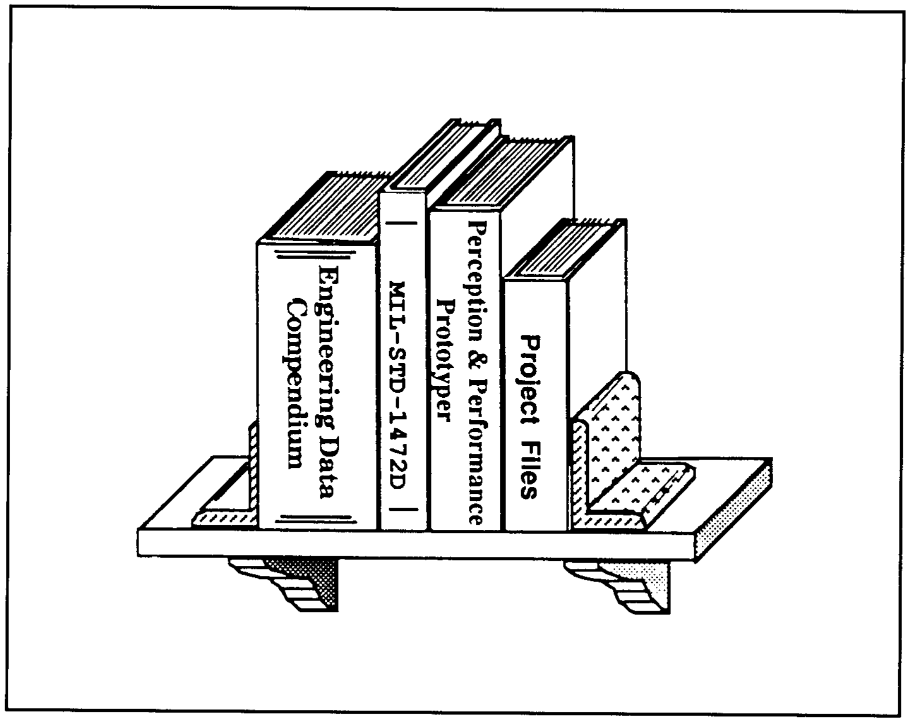


Figure 2. The CASHE Bookshelf.

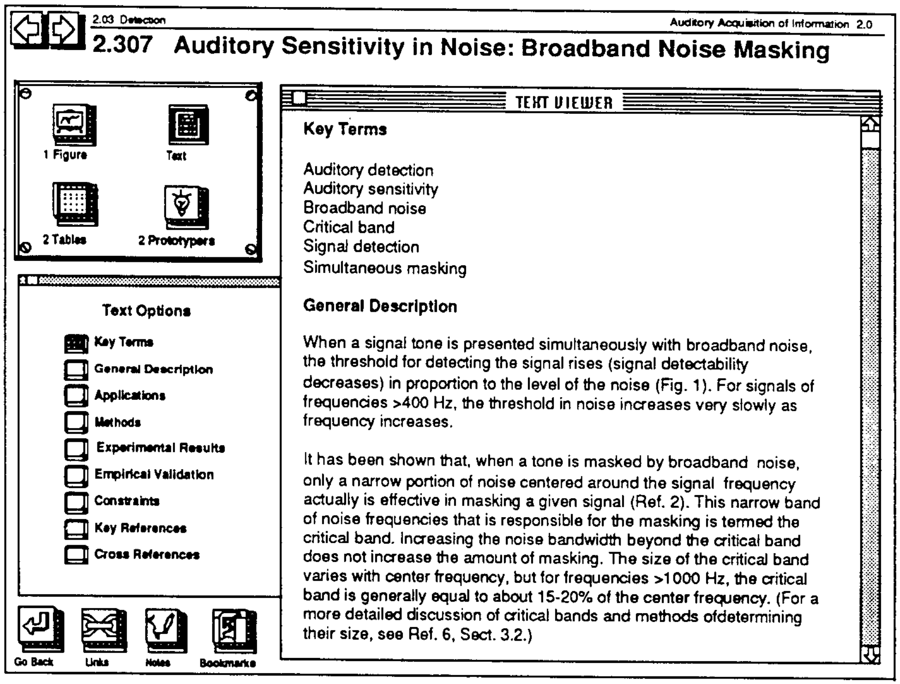


Figure 3. Electronic representation of an entry from the Engineering Data Compendium showing TextViewer.

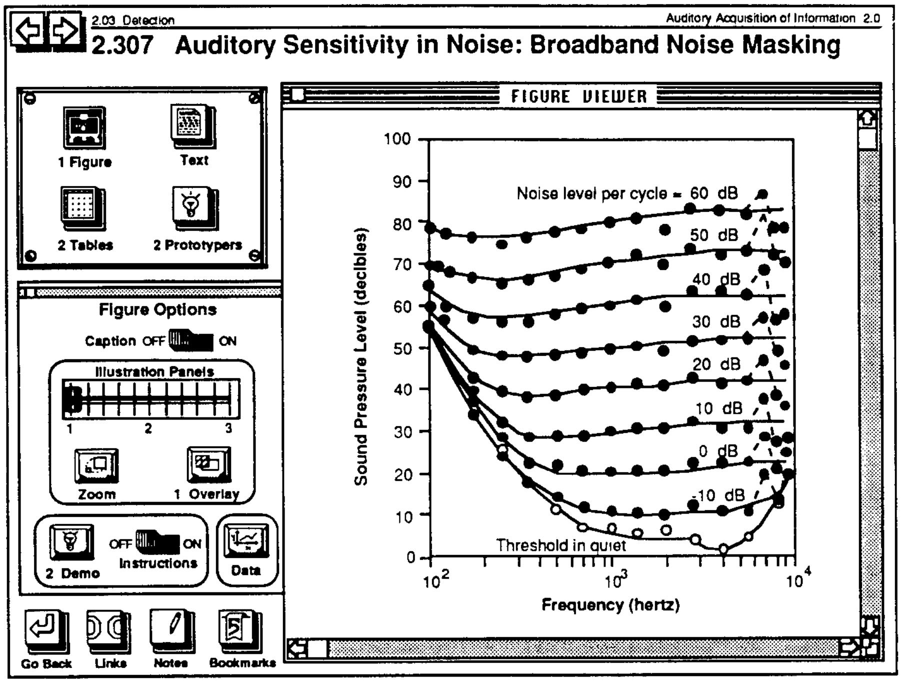
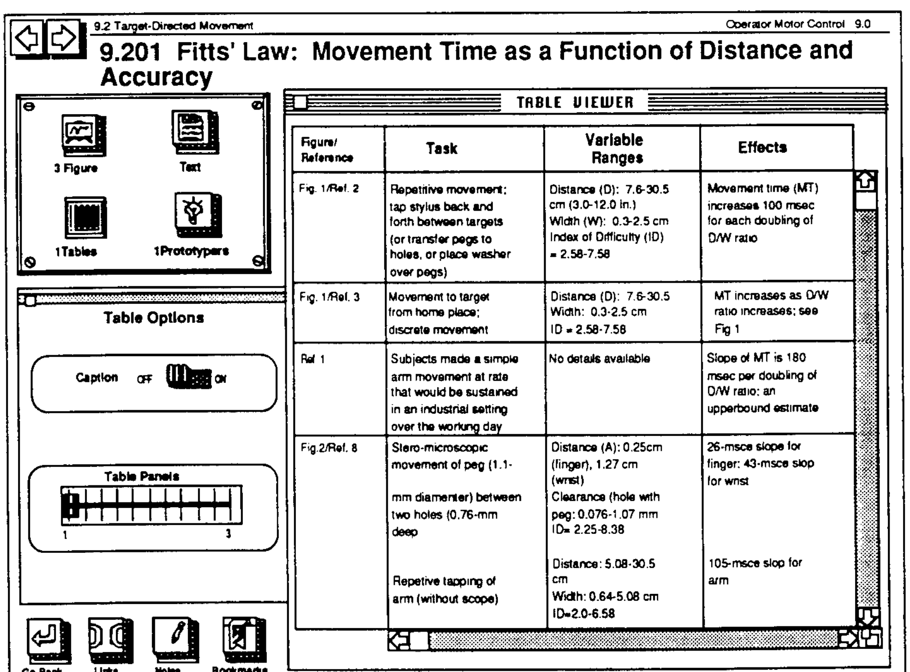


Figure 4. Electronic representation of an entry from the <u>*Engineering Data Compendium*</u> *showing FigureViewer.*



Figure/ Reference	Task	Variable Ranges	Effects
Fig. 1/Ref. 2	Repetitive movement; tap stylus back and forth between targets (or transfer pegs to holes, or place washer over pegs)	Distance (D): 7.6-30.5 cm (3.0-12.0 in.) Width (W): 0.3-2.5 cm Index of Difficulty (ID) = 2.58-7.58	Movement time (MT) increases 100 msec for each doubling of D/W ratio
Fig. 1/Ref. 3	Movement to target from home place; discrete movement	Distance (D): 7.6-30.5 Width: 0.3-2.5 cm ID = 2.58-7.58	MT increases as D/W ratio increases; see Fig 1
Ref 1	Subjects made a simple arm movement at rate that would be sustained in an industrial setting over the workng day	No details available	Slope of MT is 180 msec per doubling of D/W ratio: an upperbound estimate
Fig.2/Ref. 8	Stero-microscopic movement of peg (1.1- mm diamenter) between two holes (0.76-mm deep Repetive tapping of arm (without scope)	Distance (A): 0.25cm (finger), 1.27 cm (wrist) Clearance (hole with peg: 0.076-1.07 mm ID= 2.25-8.38 Distance: 5.08-30.5 cm Width: 0.64-5.08 cm ID=2.0-6.58	26-msce slope for finger: 43-msce slop for wrist 105-msce slop for arm

Figure 5. Electronic representation of an entry from the <u>*Engineering Data Compendium*</u> *showing TableViewer.*

Users can access and navigate the CASHE-PVS Version 1.0 information base contained in the four volumes. The first three volumes may be opened and closed, leafed through, annotated, tagged with bookmarks, and include a facility for comparing "pages." The fourth volume may only be opened, closed, and leafed through. The many operations that one normally performs with books are retained or augmented. This ability to annotate the information base enhances its personal meaning and value.

File viewers allow the user to view, interact, manipulate, and analyze the information contained in the document entries. In CASHE-PVS Version 1.0 these consist of a TextViewer, a FigureViewer, and a TableViewer. These viewers allow access to different data types while keeping the overall context of a unified entry.

The TextViewer (see Fig. 3) displays the text portions of an entry. This data entry format is designed to facilitate quick and efficient viewing of the data entries and navigation to other pertinent entries.

The FigureViewer (see Fig. 4) displays both data graphs and illustrations. It allows the user to select figure panels, control the display of overlays, zoom the figure scaling in or out, and turn the figure caption on or off. Where applicable, the user can select either an animation or interactive demonstration which further illustrates the entry. If the figure is a data graph, the user can access the DataViewer to further explore analytic relationships.

The TableViewer (see Fig. 5) displays entry tables. The first row and column of a table contain the row/column titles. The user can scroll horizontally through the table with the first column remaining "fixed" while the remaining columns "slide" under the column title. Likewise, the user can scroll vertically with the top row remaining "fixed" and the remaining rows sliding under the row title. The Table Options panel allows the user to select multiple panels and turn the caption on or off.

Continued on page 4

Visualization Tools

These are provided to aid the user's understanding and application of the information available within the reference sources on the Bookshelf. First, users are able to manipulate and transform quantitative and graphical relationships contained in the information base or brought in from external sources through a DataViewer interface. This provides the user with the capability to view, manipulate, and display data. Figure 6 portrays the selection of an existing XY graph, digitization and storage of the resulting XY values in a table, and transformation of those data values into a new function, Z.

Four primary functions are available in the DataViewer: Data Definition, Data Acquisition, Data Transformation, and Data Presentation. The Data Transformation function will support both monadic and dyadic transformations and limited analyses, including statistics and polynomial curve-fitting. The Data Presentation function offers four display formats: histograms, scatterplots, line graphs, and tables.

Second, a collection of test benches referred to as the Perception and Performance Prototyper (P^3), has been provided. Using the test bench metaphor, P^3 allows the user to manipulate and interactively experience the variables discussed in the references on the Bookshelf.

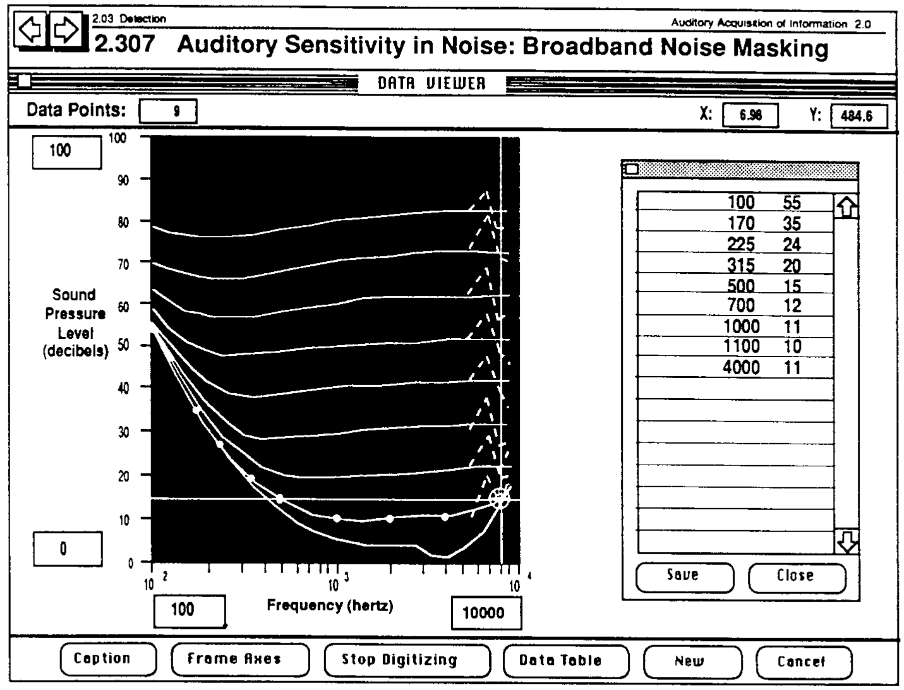


Figure 6. Electronic representation of an entry from the Engineering Compendium showing DataViewer.

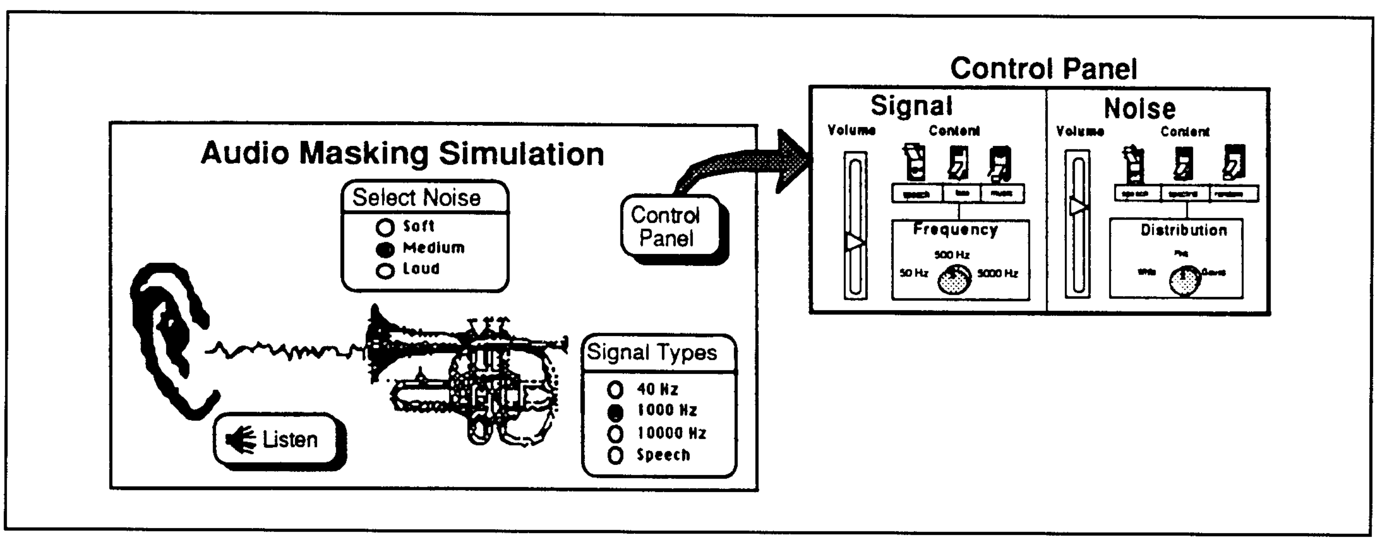


Figure 7. Operation of the Perception & Performance Prototyper: The audio-masking test bench.

It is a unique feature of CASHE-PVS Version 1.0 which allows the user to manipulate and experience alternative representations of the technical data found in the reference sources in the Bookshelf. For example, after consulting the *Compendium* concerned with how noise level may affect audio sensitivity, the user may have uncertainty regarding the relevance of the data to specific conditions. Using P , users will actually be able to access a test bench and custom control panel that will support test and experimentation with the combinations of variables with which they are more directly concerned. In the instance illustrated in Figure 7, the user can dial up relevant signal-to-noise conditions and can then experience the resulting aural phenomenon, first-hand. Minor variations in the phenomenon can be explored by selecting different noise levels or signal types.

Conclusions

CASHE attempts to circumvent the problems encountered by designers in attempting to access, understand, and apply ergonomics data by providing a comprehensive, integrated, and easy-to-use system. This system will include the most important and frequently used ergonomics handbooks, but in electronic format. Its hypertext structure will allow data from multiple sources to be brought together for analysis. In addition, it will present data in alternative formats, as well as traditional ones. Furthermore, specially created visualization tools will allow designers to manipulate data that typically cannot be done with most systems.

As ergonomics data becomes more available and usable as a result of CASHE, designers will be more inclined to use it. This, in turn, will result in the design of more user-friendly systems which will improve crew performance, reduce workload, and reduce the likelihood of human error.

CASHE-PVS Version 1.0 is a first attempt by the Human Engineering Division of the Armstrong Laboratory to provide designers with an ergonomics "tool" for developing efficient and safe human-operated systems. ●

Donald L. Monk is Program Manager of the CASHE Program in the Human Engineering Division of the Armstrong Laboratory, Wright-Patterson Air Force Base, OH.

Kenneth R. Boff, Ph.D., is Chief of the Human Engineering Division of the Armstrong Laboratory.

CASHE

The COTR Speaks

Reuben L. Hann

First of all, the *Gateway* staff and I want to extend our thanks to all the readers who have already sent back their mailing-list reply cards. The response has been overwhelming—and gratifying. After only the first notification, more than 2000 persons have taken the trouble to fill out and return their cards. That is about one-third of our circulation! Although the primary purpose of the response cards is to update our master mailing list, for us it is also an indirect measure of the value of *Gateway* to the readers: If you were not finding this newsletter interesting or useful, you would not bother to take the trouble to reply. Your response tells us that we are doing something right. We will try to justify your confidence in us. By the way, if you have not sent in your update card, there is one in this issue; please take a minute to fill it out. Thanks.

The lead story in this issue of *Gateway* describes the Computer-Aided Systems Human Engineering (CASHE) system, under development at the Human Engineering Division of the Armstrong Laboratory. It takes advantage of the new CD-ROM technology for storing and accessing large amounts of multi-media information in a compact, transportable format. CASHE will integrate human engineering information into all aspects of the human/system design decision-making process. I am sure you will find this approach an exciting solution to the long-standing problem of providing ergonomics support to the designer in a form which is truly useful.

We were pleased to have Jens Rasmussen, Professor of Cognitive Engineering, RISO National Laboratory and the Technical University of Copenhagen, Denmark, as the second speaker in the Armstrong Laboratory Colloquium Series. Prof. Rasmussen spoke on the topic of "Virtual Ecology of Work and System Design." In this issue CSERIAC staff member Dr. Ron Schopper provides a synopsis of the presentation; it is followed by excerpts of a conversation Ron and I had with Prof. Rasmussen during his visit.

Authors Westermann, Heasly, and Welch describe a new tool for including human/system integration and human factors engineering in the acquisition process: IDEA (Integrated Engineering/Decision Aid). It is based on Macintosh Hypercard stacks and provides the analyst with guidelines, data, and assorted tools designed to ease the planning and execution

Calendar

June 10-14, 1992
Denver, CO
Annual International Industrial and Safety Research Center Conference, sponsored by the International Foundation for Industrial Ergonomics and Safety Research, in cooperation with the University of Alberta and the Industrial Commission of Ohio, at the Holiday Inn. Contact S. Kumar, Dept. of Physical Therapy, 3-75 Corbett Hall, University of Alberta, Edmonton, Alberta T6G 2G4, CANADA; (403) 492-5979, fax (403) 492-1626.

July 29-August 1, 1992
Bloomington, IN
14th Annual Conference of the Cognitive Science Society, at Indiana University. Contact John K. Kruschke, Conference Chair, Cognitive Science Program, Psychology Bldg., Indiana University, Bloomington, IN 47405; (812) 855-4658, Email: cogsci92@ucs.indiana.edu.

October 12-16, 1992
Atlanta, GA
36th Annual Meeting of the Human Factors Society, hosted by the HFS Atlanta Chapter, at the Westin Peachtree Plaza Hotel. Contact HFS, P.O. Box 1369, Santa Monica, CA 90406-1369; (310) 394-1811 or (310) 394-9793, fax (310) 394-2419.

July 12-16, 1992
San Jose, CA
AAAI-92/IAAI-92, Tenth National Conference on Artificial Intelligence and Fourth Annual Conference on Innovative Applications of Artificial Intelligence, sponsored by the American Association for Artificial Intelligence, at the San Jose Convention Center. Contact AAAI-92/IAAI-92, 445 Burgess Dr., Menlo Park, CA 94025-3496; (415) 328-3123, fax (414) 321-4457.

August 24-27, 1992
Nottingham, UK
3rd International Conference on Visual Search, organized by the Applied Vision Association, Ergonomics Society, and British Machine Vision Association and Society for Pattern Recognition, at the University of Nottingham. Contact TICVS, Academic Radiology, University Hospital, Queens Medical Centre, Clifton Blvd., Nottingham NG7 2UH, UK; 44 (0) 602-0709442, fax 44 (0) 602-709140.

October 25-28, 1992
Hamilton, Ontario, CANADA
Human Factors Association of Canada/Association Canadienne d'Ergonomie 25th Annual Conference, "The Economics of Ergonomics." Contact HFAC/ACE Office, 6519B Mississauga Rd., Mississauga, Ontario L5N 1A6, CANADA; (416) 567-7193, fax (416) 567-7191.

of the purchase and fielding of new military systems.

The Armstrong Laboratory's Human Engineering Division, like many other Department of Defense organizations, recently underwent a reorganization. In this issue I have written an article which gives some background, the rationale, and a description of the process. I have also highlighted some of the research programs in the various branches of the Division. Incidentally, we would like to feature the restructuring of other DoD human engineering organizations in future issues of *Gateway*.

In our final article, CSERIAC staffer Frank Gentner and co-author Mona Crissey describe the "Liveware" survey being conducted by CSERIAC for NATO and the Office of the Assistant Secretary of Defense for Force Management and Personnel. The survey will catalog all known tools, methods, and databases which aid in the Human Systems Integration (HSI) process of new systems acquisition. HSI is a new domain for CSERIAC; in the future we will be providing support as a central clearing house for information in this important area.

I hope you find this *Gateway* interesting and informative. As always, we solicit your feedback and suggestions for articles. If you have written something you think would be of interest to the general human factors community and would like to have it considered for the *Gateway*, please contact me or the Editor, Jeffrey A. Landis. ●

Reuben "Lew" Hann, Ph.D., is the Contracting Officer's Technical Representative (COTR) who serves as the Government Technical Monitor for the CSERIAC Program.

Request for Topics For State-of-the-Art-Reports (SOARS)

CSERIAC makes every effort to be sensitive to the needs of its users. Therefore, we are asking you to suggest possible topics for future SOARS that would be of value to the Human Factors/Ergonomics community. Previous SOARs have included *Hypertext: Prospects and Problems for Crew System Design* by Robert J. Glushko, and *Three Dimensional Displays: Perception, Implication, Applications* by Christopher D. Wickens, Steven Todd, & Karen Seidler. Your input would be greatly appreciated. We are also looking for sponsors of future SOARs. CSERIAC is a contractually convenient, cost effective means to produce rapid authoritative reports.

Send your suggestions and other replies to Dr. Lawrence Howell, Associate Director CSERIAC Program Office, AL/CFH/CSERIAC, Wright-Patterson AFB, OH 45433-6573.

Announcements

Course on Human Supervisory Control Offered

A summer course on Telerobotics, Automation, and Human Supervisory Control is being taught August 17-21, 1992 by the Massachusetts Institute of Technology. This course will demonstrate the application of human supervisory control to semi-automated systems. These systems include robotic arms and vehicles for space, undersea, toxic environment cleanup, manufacturing, mining, surveillance, and medical applications. The course will benefit system engineers whose designs include human operators in the role of supervisory decision-maker/controller; human factors professionals who want the latest information on modeling and designing for human-computer interaction; and research and design managers who want to better understand the challenges and problems of integrating the human operator into automated systems. The principal lecturer is Thomas B. Sheridan, Professor of Engineering and Applied Psychology, and Director of the Man-Machine Systems Laboratory in the Department of Mechanical Engineering. For further information on this course, contact Prof. Frederick J. McGarry, Director, Office of the Summer Session, Room E19-356, Massachusetts Institute of Technology, Cambridge, MA 02139; (617) 253-2101.

Anthropometry Class Offered

Did you know there is no such thing as a 95th percentile man and that it is impossible to construct a being that is 95th percentile for all measurements? Did you know that using 5th and 95th percentiles can actually fit much less than 90% of a population and can cause the design to cost more than alternative methods? Would you be interested in a class which would explain these and other pitfalls in anthropometry, as well as detail methods which work better? Such a class would describe the latest in anthropometric methods as applied to the design and evaluation of cockpits (workstations), clothing and protective equipment, including the latest in topographic and volumetric scanning of the human body. If you are interested in such a class, please respond to Wes Grooms, CSERIAC Conference Administrator, at (513) 255-4842 or DSN 785-4842.

New Journal on Teleoperator and Virtual-Environment Systems

MIT Press is pleased to announce its first journal dedicated exclusively to the field of teleoperators and virtual environments, *Presence: Teleoperators and Virtual Environments.* The complexity of the human-machine interface and associated environmental interactions affect an operator's performance, experience, and sense of presence in both teleoperator and virtual environment systems. *Presence* attempts to provide an understanding of these interfaces and interactions, as well as, the underlying design. The Editors-in-Chief are Thomas B. Sheridan, Massachusetts Institute of Technology, and Thomas A. Furness, III, University of Washington. *Presence* is published quarterly. Subscription rates are $50 for individuals and $120 for institutions. Foreign subscribers should add $14 for postage and handling, Canadian subscribers also add 7% GST. To subscribe to *Presence*, please write to MIT Press Journals, 55 Hayward St., Cambridge, MA 02142; (617) 253-2889.

Decrease in CSERIAC SOAR Charge

CSERIAC has periodically published state-of-the-art reports (SOARs) on a variety of topics relevant to the human factors community. It has been CSERIAC's intent to simpy recover costs incurred for production of these SOARs. However, the high cost of contracting various experts to write these, combined with the high cost of printing, has resulted in SOARs that were priced beyond what most ergonomists, psychologists, designers, and engineers could afford. To make the CSERIAC SOARs more readily available to professionals in the field, the CSERIAC Program Office has decreased the price from $75 to $35, effective immediately. This price reduction will apply to SOARs already published as well as future SOARs, until further notice.

Armstrong Laboratory Colloquium Series: Virtual Ecology of Work and System Design

Jens Rasmussen

Editor's note: Following is an abstract based on Prof. Rasmussen's presentation as the second speaker in the Armstrong Laboratory Colloquium Series: The Human-Computer Interface. Dr. Aaron Schopper, CSERIAC Chief of Technical Services and Analyses, prepared this abstract.

How can we design information systems to support work in organizations functioning within a rapidly changing technological environment that is tied to equally rapid changes in marketing conditions and company policies? In such environments there frequently exist an immense variety of options ("degrees of freedom") with respect to "what to do when and how." When a worker (a "human actor" who is a dynamic being that is both goal directed and adaptive) is placed in such an environment, it becomes a combination that is extremely complex to assess. To develop effective information support systems for such an environment is a very demanding task.

To understand and anticipate the worker's behavior, one must identify the "constraints" that shape behavior and the "subjective performance criteria" that he or she applies when making a decision regarding work performance. Pertinent to the issue is the fact that behavior has a "prehistory" that reflects the aggregate effects of prior choices and decisions. In modern organizations, there is often very little pertinent prehistory to guide the worker. Work environments of past organizations were often bound by tradition, longstanding rules, and precedents that provided the worker with the contextual information to assist him or her in making a decision. In contrast, there are apt to exist far fewer formal rules, and much less time for traditions to form or for informal rules to develop in present-day organizations. Consequently, normative rules and advice systems frequently are inadequately developed in many modern work environments.

To meet the needs of the worker, information systems must represent the existing state of affairs in the work environment as transparently as is possible in terms of the objectives to be pursued and the constraints that exist to bound his or her domain of alternatives. The framework to be pursued must represent both the physical characteristics of the work environment as well as the subjective interpretation of same by the "actors" involved. To be able to effectively anticipate information needs and behaviors, the framework must be able to relate and translate the existing physical work environment to descriptions of human resource profiles and subjective preferences. Additionally, the analysis strategy must be an economical one; all possible alternatives cannot be identified and evaluated. One must develop an analysis strategy that converges rapidly upon a delimited set of alternatives. To accomplish this requires a stepwise narrowing of the degrees of freedom available to a worker. This reflects a successive process of delimiting the alternatives by identifying the topographic aspects of the physical workspace; explicitly identifying the goals, constraints, means (and amount of time available) to the actor; and delimitating the decision task and associated mental tasks and emotional factors.

Albeit all possible alternatives cannot be analyzed, the decription of the work territory should identify the entire network of means-end relations for all pertinent activities. The means-end representation is structured in several levels of abstraction, ranging from the physical aspect of the task environment, through descriptions of the physical activities and processes, and more abstract descriptions of concepts and functions (functionality/intentionality) used to set priorities, allocate resources, and compare the results with the even more abstract goals and constraints formulated at the upper levels. An important feature of this complex means-end hierarchy is the resulting many-to-many mapping found among the levels, a feature that admits—and creates the need for—the complex information support systems required to support efficient, safe work environments in modern organizations.

To build an appropriate framework and accommodate such a variety of means-end relationships is a complex endeavor necessitating changes in the level of abstraction. Albeit such changes entail shifts in both the concepts and the structure, the different levels represent information about the same physical world. At each level of abstraction, the information serves as a set of links between the representation of the material work environment and its resources on the one hand, and the representation of the ultimate goals and objectives on the other. Thus the means-end hierarchy is formed by a progressive set of conceptual transformations reflecting the purposes and intentions at the higher levels, and the physical constituents at the lower end (see Table). The critical human function at each level is that of decision making—a task that focuses on the need to identify and resolve discrepancies between the existing functional state of affairs and the intentions derived from the ultimate goals.

In terms of implications for system designers, it is apparent that when tasks have large discretionary compo-

Decision Making Modes

- **Rational, analytical reasoning; situation analysis, goal evaluation, decision, and planning**
- **Know-how, choice among perceived alternatives in context; dynamic control of work environment**
- **Define increasingly specific context; decision evolves without choice**

nents, the utility of the application of the more traditional task analysis approach is questionable. Such applications yield the greatest benefit in closely coupled systems wherein task components are bound in rather strict closely bound sequences (e.g., manufacturing processes). In instances of loosely coupled tasks (e.g., the operation of a city), where the intentional (versus the functional) constraints are most relevant, the complexity is increased markedly. While it is hoped that intentions can be explicitly communicated, it is often the case that "intentionality" must be inferred by the workers via their judgments of their co-workers' behaviors and communications (often non-verbal and informal). Thus the discernment and interpretation of the "intentional" communications pose the greatest problem for the designer of information support systems.

he interpretation of intentions and cause by a worker depends, in large part, upon the mental strategies applied. The choice of strategy depends upon the competence and performance criteria of the individual. Such strategies range from very formal ones, which define the extent of the cognitive load imposed, to the more "natural" strategies applied in everyday work situations which entail very frequent shifts among the brief applications of formal strategies in response to very different subjective and situation-dependent factors (e.g., time required versus time available, availability of a mental model, number of observations required to use the strategy). Such shifts in strategies represent very effective ways of circumventing local roadblocks along the path of work. Information support systems should support all the strategies relevant to a task to permit workers to shed mental work load via shifts among strategies.

In familiar circumstances, interaction is based on real-time, multivariable, synchronous coordination of physical movements with a dynamic environment. Automatic action patterns are activated and chained by cues perceived as signs; no choice among alternatives is required. When the situation demands more cognitive effort, decisions and actions are based on rules, which,in turn, are predicated on the invocation and updating of an internal model of the work situation. The result of comparisons between the perceptions of the real world and the internal model form the basis for response. An important point for the designers of interfaces is that when a skilled professional encounters a mismatch between an intuitive expectation and the present state of affairs, he does not enter a general problem-solving mode. Instead he or she perceives only a limited set of alternatives for action. Such decision makers are not subject to "information input" from an environment that has to be analyzed; they are asking very specific questions. Experts will need no more information than is needed to resolve the choice among their limited set of perceived options. Designers who are not thoroughly familiar with a work domain often overestimate the amount of information required by a specialist to make a decision. Yet, at the same time, they tend to underestimate the complexity of a display which is acceptable to an expert immersed in the work context if it is properly structured.

Displays required to support skilled routines should be structured in a manner that isomorphically depicts the part-whole repertoire of automated sensorimotor patterns. Those designed to support ruled-based behaviors should provide consistent one-to-one mapping between work constraints and the cues and signs needed to release familiar actions. Displays that are to serve the needs of those engaged in problem solving should depict the work domain as an abstraction to serve as an externalized mental model that will support knowledge-based action and planning.

When tasked with supporting decision makers regarding discretionary tasks within dynamic work environments, it is generally more effective to design interfaces that display the constraints and the options available than it is to offer procedural guides, just as it is more effective to provide maps to a navigator than it is to provide specific route instructions when faced with changing targets and goals in the face of unknown potential roadblocks.

For potentially high-hazard systems, e.g., industrial process plants, design priorities for decision support systems are related to performance in the rare situations of disturbance punctuating long periods of stable automatic operation. In that circumstance, the aim of interface design is to provide information systems and displays that can support skill and rule-based perfor-

Continued on page 10

mance during normal operations and, at the same time, can serve knowledge-based analysis during disturbances. In well-structured systems, the diagnosis associated with disturbance control can be effectively accomplished by using strategies that assist in the process of comparing the actual state of the system with the normal, intended state in an effort to locate the location of the disturbance within the relational network. Visual support of such diagnosic efforts can be provided by a display that overlays actual and intended states at different levels of representation. The intended operating states and the boundaries of unacceptable operation should be represented by an overlay of the functional structure and states. The levels of abstraction employed will differ as well. At the global level, the composition should reflect the overall structure; at the lower levels, the composition should map closely to actions on physical items or elements (whose form should match population stereotypes). At the intermediary, configural level, activity is related to functional relations for which stereotypic representations are frequently found within the drawings contained in manuals and texts associated with the profession. An experimental example of such a display is provided in the figure for a nuclear power reactor.

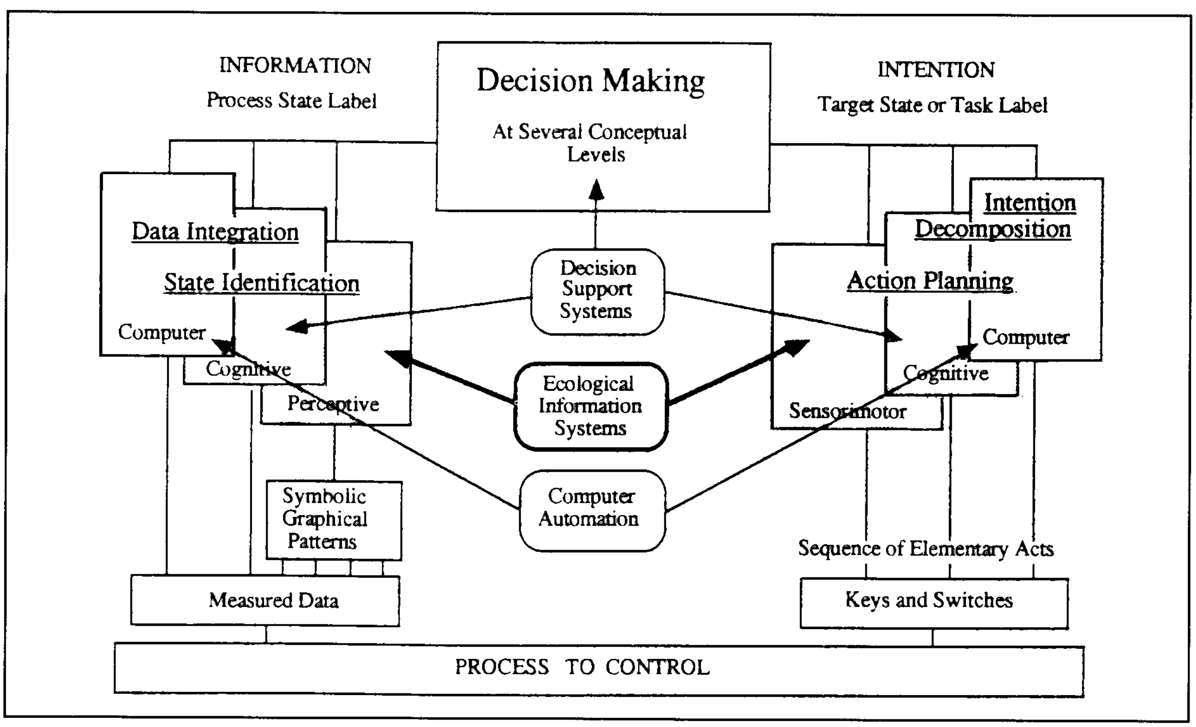
The approach I have described here is conceptually compatible with the approach developed at the Armstrong Laboratory with AKADAM. In both cases, the need has been realized for a method to represent the complexity and degrees of freedom found in advanced human-machine systems, while, at the same time, structured formalisms such as SADT and EIDEF representations are found useful for system specifications.

One major difference in focus of the two approaches offers a promising potential for joint development. The AKADAM approach focuses on an analysis and representation of the *users' knowledge* base and a large database from analysis of pilots' concept maps is established. The new interpretation tools being developed greatly facilitate analysis from different user perspectives as found in different task situations.

I have focused my approach on the identification of the behavior-shaping constraints in a task situation from an analysis of the actual work *environment* and the intentionality of the designers and found an integration of the RISO framework for cognitive work analysis and the AKADAM approach to be very promising for an explicit description of the propagation of behavior-shaping constraints (in terms of functional as well as intentional relationships) from the designer, through training of system users/operators and their subsequent adaptation to the work requirements, onto their knowledge base.

In conclusion, I suggest that an integration of the two approaches could serve prediction of user responses to new work systems and interface designs and, therefore, to generalize the results from aviation and pilot studies to be used more widely in the civil industry. ●

Jens Rasmussen is a Professor of Cognitive Engineering at the RISO National Laboratory, and the Technical University of Copenhagen, Denmark.



Modes of work support.

Armstrong Laboratory Colloquium Series:

A Conversation with Jens Rasmussen

Editor's note: The following is an edited transcript of a conversation with Professor Jens Rasmussen, RISO National Laboratory and the Technical University of Copenhagen, Denmark, who had just made a presentation as the second speaker in the Armstrong Laboratory Colloquium Series: The Human-Computer Interface. The interviewers were Dr. Lew Hann, CSERIAC COTR, and Dr. Aaron Schopper, CSERIAC Chief of Technical Services and Analyses.

CSERIAC:
I notice that your affiliation at the institute is with the Cognitive Engineering Department. Could you explain how "cognitive engineering" is related to human factors or ergonomics?

Prof. Rasmussen:
We call it Cognitive Engineering to avoid the term "human factors," which, to us, is more related to coming in as experts and making refinements to an existing interface. Cognitive Engineering on the other hand, deals more with designing information systems so that the basic structure and functioning of the system serve the user. That is, human factors normally is seen as a kind of craft where experts are called in to help sort out problems, where-as cognitive engineering is a cross-disciplinary approach to a design problem.

CSERIAC:
I read recently, following the third crash of an Airbus A320, that pilots are talking about refusing to fly this aircraft. The A320, as you know, has a highly computerized cockpit, with multi-purpose displays. The issue here seems to be one of "trust" in the system. I understand you have been looking at this problem.

Prof. Rasmussen:
I think it is a very important issue. We have been discussing making these kinds of information systems, and that they should be adaptive to the user. One of the problems is that we are losing people's confidence; if people don't understand what is going on behind an automatic system, they lose trust.

CSERIAC:
One of the pilot's complaints about the A320 is that the system doesn't permit violent flight maneuvers. Normally this is desirable, but in the case of an emergency, such extreme control inputs might be necessary.

Prof. Rasmussen:
The designer should protect his design by putting constraints on the pilot, but should also be sensitive to the fact that the pilot sometimes has other priorities which might require going beyond the constraints. That's the reason we are working so hard on these ecological displays. You must make the boundaries of the system visible to the user, but we don't think you should constrain them to be within the intention of the designer, if you can identify situations where other priorities are operating.

CSERIAC:
Much to the consternation of many ergonomics practitioners, a recent automobile advertisement in American television defined ergonomics as "fitting the person to the machine." This is, of course, the opposite of what we have been trying to convey over the years. When you talk of "adaptation" are you using it in the sense of the person adapting to the system, or the reverse?

Prof. Rasmussen:
It is not so simple to define it in either extreme. I think you should make it possible for the system and the person to "meet" somewhere in the middle. If one talks about fitting the system to the person, it should be designed to fit the person as he will be *after* he has adapted to the characteristics of the system. You want to make a system where people adapt to an effective way of operating based on their preferences; but this does not mean you are fitting the system to the person. Whatever you do, the person will adapt to your design; after working in the system for a while they are always different from when they started. The problem is to find out how to design a system so that it matches the capabilities and preferences of the persons *when* they have adapted to the system. User opinions have value, but system design should not be based on that alone. More important are the implicit aspects such as subconscious preferences, value structures, and resources.

The problem is to find out how to design a system so that it matches the capabilities and preferences of the persons *when* they have adapted to the system.

CSERIAC:
Dr. Gary Klein has been doing extensive work in *naturalistic decision making*. I understand you are also working in this area. How did you get involved, and why do you feel it is important?

Prof. Rasmussen:
We arrived at the problems surrounding naturalistic decision-making independently of Gary Klein and his associates. It evolved from our error studies, where we found in many situ-

Continued on page 12

ations people were running into problems, because they were making a decision based on some cues in the environment which are not relevant. We found, as we studied adaptation, that although people are supposed to attend to all the information defining the attributes of the decision to be made and the action to take, they in fact take the path of least resistance. That is, they usually consider only a couple of options based on the context. Most decision-making situations are occurring in a continuous task setting, where the person is very familiar with the context, and they know pretty well how many options they have to choose from in any decision situation. In any given context you only ask for the cues which will give you the choice; you only need one bit of information to choose between two alternatives. Ecological interfaces provide this kind of information.

CSERIAC:

Based on your long experience in the field of ergonomics, where do you think we should be investing our resources for the greatest payoff?

Prof. Rasmussen:

I really think some resources should be invested in getting some cross-disciplinary research going. I think it's so important to have some studies going on where you have experts from various domain areas working simultaneously on a problem. So, for example, you might have an expert studying behavior-shaping constraints, a cognitive psychologist looking at naturalistic decision-making, and a perception psychologist examining the problem of direct perception of invariants in the environment. In this way, you could get a more integrated basis for discussing matching systems to people. It is not a nice academic research problem which we can resolve in a short time with a professor and graduate student. By the way, in this respect, I think that the Armstrong Laboratory here has the right capability to pursue such research. You can make long-term plans, which is impossible in academia, and you can conduct cross-disciplinary projects in complex settings. ●

Scenes from the Armstrong Laboratory Colloquium Series:

Professor Rasmussen lectured in the auditorium of Building 441, the Bioacoustics Laboratory of the Crew Systems Directorate, Armstrong Laboratory, Wright-Patterson Air Force Base. Photo by Dan Churchill.

Following the lecture Professor Rasmussen talked with many of the attendees on an individual basis. Photo by Dan Churchill.

IDEA: The HSI/HFE *Integrated Decision/Engineering Aid*

Dean P. Westerman
Christopher C. Heasly
Daniel L. Welch

Last year the Department of Defense approved DoD Directive 5000.1 and DoD Instruction 5000.2. These documents formalize Systems Acquisition Policies and implementation of Human Systems Integration, or HSI as it has become known. The requirements are driven by the need to develop systems that "...meet the operational user's needs..."

The objectives and focus of HSI draw upon the U.S. Army's MANPRINT initiative in that both programs recognize the need and benefit of considering the "user" as an integral component of the system.

Integrated Decision/Engineering Aid (IDEA) is an automated system developed by the U.S. Army Human Engineering Laboratory, U.S. Naval Space and Warfare Command, the U.S. Naval Sea Systems Command, and Carlow International Incorporated. The system is a collection of integrated tools used in support of Human Factors Engineering analyses. Originally developed for standardizing MANPRINT activities within the U.S. Army Human Engineering Laboratory, it is being updated to reflect the requirements of DoD Directive 5000.1 and DoD Instruction 5000.2.

IDEA is currently implemented on the Macintosh family of computers (select portions of IDEA are to be converted for use on DOS machines).

IDEA provides an HFE/HSI analyst with the guidelines, data, and tools required to integrate HFE into acquisitions of non-developmental items, product improvements, and new system developments. The primary focus of IDEA is on guiding the analyst through the steps required to conduct HSI/HFE activities, and on automated methods to conduct required analyses. Additional efforts were aimed at efficient use of data throughout. For example, having constructed a flow diagram of an emerging weapon system, an analyst can use the resulting task inventory in no fewer than five other analysis tools. Not only does this reduce the time required to conduct analyses, it serves to integrate the analyses (a primary goal of both MANPRINT and HSI) making them easier to interpret (and presumably more rational).

The types of aides include Process Tools, System Notes, Analytical Tools, Information Tools, and Productivity Tools. Each of these is briefly described below.

Process Tools

IDEA is organized around the Material Acquisition Process (MAP). Each phase of the MAP (e.g., Mission Needs Determination, Concept Exploration & Definition) is represented in IDEA as a process. The highest level process, referred to as the *phase*, identifies the relationships between discreet or related activities defined as *steps*. A *step* in turn has a lower level or more defined set of activities termed *sub-steps*. Finally, each sub-step is decom-

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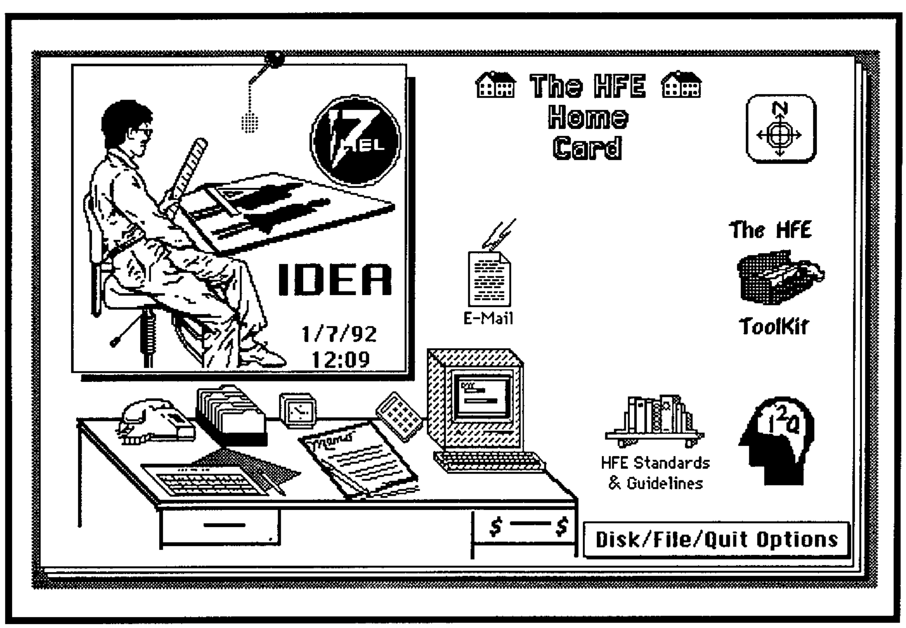


Figure 1. The IDEA Home Card permits rapid access to all elements of the automated system.

posed into a series of activities. An analyst "navigates" through the various levels of the Process by "pointing" and "clicking" the mouse. Figure 1 shows the Home Card which is the starting point for the system.

These activities detail the required steps, by sub-steps, sub-processes, and activities required to conduct the HSI/HFE analyses for that specific phase.

The Process Tools were developed to drive/support the use of:

- System Notes Tool
- Productivity Tools
- Analytical Tools

At the level of the HSI/HFE Process for a specific phase of the materiel acquisition process (MAP), the analyst is presented with a sequence of interrelated steps which constitute the activities and activity sequence to be accomplished while applying HSI/HFE in that particular phase. Each step of this process is a button which can be selected by the analyst to acquire additional information concerning that step.

At the *Step* level (Fig. 2), the analyst is presented with a full description of the selected process step. The elements of the description are controlled by buttons on the step level display. Selecting the step button itself presents an overview of the step, including objectives and requirements. The "Relationship to the MAP" button displays how the selected step is related to the activities, events, and products of the overall MAP. The "Inputs" and "Outputs" buttons, when selected, display the required information for entry to the step and the informational products resulting from the step. The "Work Summary" button displays what steps have been completed in the application of HSI/HFE for that particular system and the "Sub-Process" button takes the analyst deeper into the process, to a display of the sequence of sub-steps for that particular step.

At the *Sub-Process* level (Fig. 3), the analyst is presented with a display of the sequence of sub-steps required to carry out the process step. Each sub-step is represented by a button, selec-

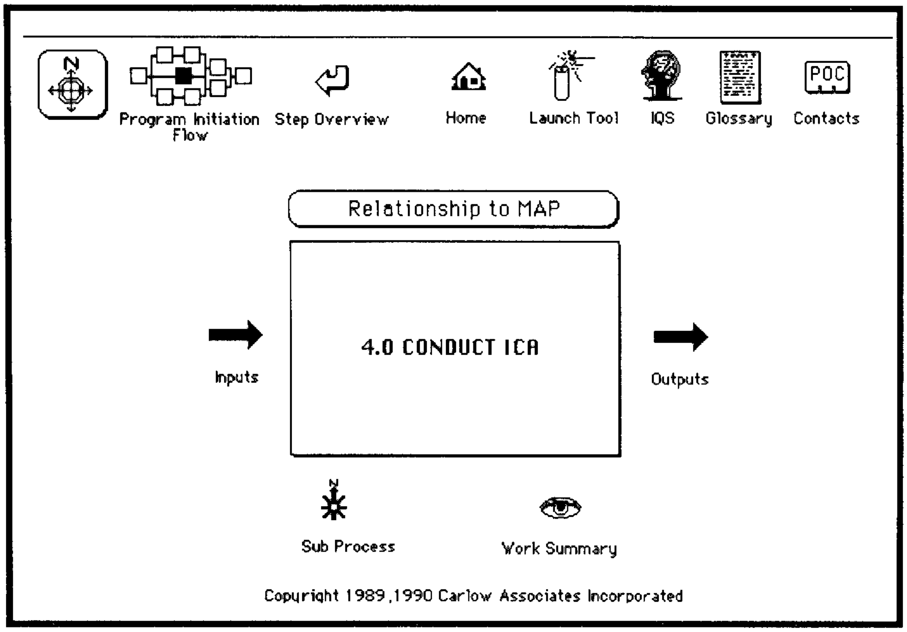


Figure 2. Each element of the "Step" screen is a hotfield. Clicking on any element will provide additional information to the user regarding that area.

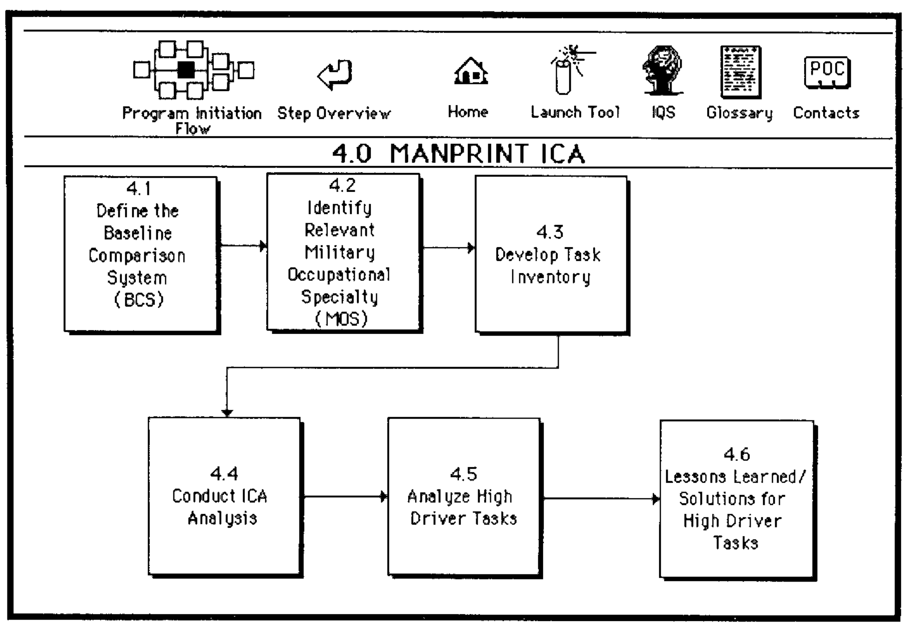


Figure 3. Each HFE/MANPRINT step can be further described. Clicking on any box on this screen will provide additional information on inputs, required activities, and output products for each sub-process.

tion of which presents additional information and guidelines concerning the sub-step. When the analyst selects a sub-step button, a display presents the inputs, required activities, and products of that particular sub-step. Activities include the specific actions needed to perform the sub-step. At the Sub-Process level, the analyst can select the notebook, which provides the capability to identify and record requirements and concerns for that sub-step. The notebook represents a report generator for the HSI/HFE application for the *system* under-development.

System Notes

The System Notes Tool content was developed to provide a centralized facility in which all documentation relevant to the developing system is to be maintained. The tool is structured around two related concepts.

The first, an assumption, is that the HSI/HFE Analyst will be working on several systems at any point in time, and will need to document efforts separately. Therefore, the analyst is strongly encouraged to keep a separate notebook for each system.

The second issue is that the notebook should help to focus the analyst's activities. Accordingly, the System Notes Tool includes all the activities required to complete all sub-process sub-steps and activities for all steps of each phase. Further, the activities listed can be used as a checklist to verify the completeness of the activities/analyses.

Analytical Tools

Analytical Tools currently available to facilitate the HSI/HFE Analyst's efforts include:

- IDEA Comparability Analysis Tool (ICAN) - used to identify high driver tasks/conditions and lessons learned from predecessor systems
- IDEA Role-of-the-Soldier Tool (IROS) - used for function allocations and determination of roles-of-the-soldier in system operation and maintenance
- IDEA Automated Critical Task Analysis Tool (I-TASK) - used to conduct fundamental HFE critical task analyses
- Functional Flow/Task Sequencing Tool (NETWORK) - a graphic functional flow/task sequencing tool used to establish the relationships among tasks especially developed as a front-end to SIMWAM
- Simulation for Workload Assessment and Modeling (SIMWAM) - simulation model for assessing multi-operator task networks and evaluating alternate role of man concepts and system design alternatives
- IDEA Issue Tracking Tool (ISSUE) - used for monitoring the status of specific HSI/HFE issues throughout the design process
- IDEA Tradeoff Analysis Tool (ITALIC) - used to proceduralize tradeoff studies, documenting the variables and weighing factors used in the study
- IDEA Automated HEDGE T&E Tool (I-HEDGE) - used to select design test criteria from the Human Factors Engineering Data Guide for Evaluation (HEDGE) and to maintain an electronic checklist
- IDEA Safety and Health Hazard Analysis, Developer and Evaluator (I-SHADE) - used to log identified hazards and to maintain an audit trail of their elimination or resolution.

Information Tools

IDEA includes several specialized data sources or information management tools to assist the HSI/HFE Analyst in conducting the analyses and activities of the acquisition process. Exemplar information tools include:

- HSI/HFE glossary accessible from any location in IDEA
- an automated HSI/HFE points-of-contact information system
- an IDEA automated status reporting system for each materiel system under analysis
- abstracts of US Army Human Engineering Laboratory (USAHEL) TMs, TNs and Letter Reports
- an information system containing surveys of all known HFE tools and models.

Productivity Tools

Integrated within IDEA is a collection of specialized tools developed to enhance the productivity of the HSI/HFE Analyst, including:

- a hypertext version of MIL-STD-1472D
- special computational aids such as visual field-of-view calculation and anthropometrics
- a units conversion calculator
- a means of accessing standard office productivity software (word processing, spreadsheet, database, etc.)

Current Developments

IDEA is the product of a Small Business Innovative Research (SBIR) program, currently in Phase III, between the US Army Human Engineering Laboratory (USAHEL), Aberdeen, MD, and Carlow International Incorporated of Falls Church, VA., with the participation of the US Navy. Phases I and II developed the IDEA Process through Acquisition Milestone 1. Phase III will complete the process through the rest of the acquisition process and is scheduled for release in 1992. IDEA is currently under "Beta Test" at USAHEL field offices and at the British and French Ministries of Defense. Points of contact are Dean P. Westerman, USAHEL, (301)-278-2980, and Chris Heasly, Carlow International Incorporated, (703)-698-6225. ●

Dean P. Westerman leads the Human Factors Automation Office at USAHEL, Aberdeen, MD, and is the IDEA Project Officer. Christopher C. Heasly is Vice P resident of Development at Carlow International Incorporated, Falls Church, VA. Daniel L. Welch, Ph.D., is Senior Human Factors Engineer and Manager of Continuous Process Control Systems, also at Carlow.

Meeting the Challenge of Peace: The Reorganization of the Armstrong Laboratory Human Engineering Division

Reuben L. Hann

The Cold War has ended. Military installations worldwide have been scheduled for closing. Thousands of active duty and reserve military personnel are being encouraged to retire or are being separated early. This downsizing of our fighting forces, combined with the difficult economic times, has put pressure on the DoD laboratory system to shrink and combine programs accordingly. Coupled with this pressure is the clear need— as a result of the stunning successes in Desert Storm—to maintain a technological superiority during times of peace. We must prevent technological surprise by potential adversaries, exploit scientific breakthroughs, and develop an array of technologically superior options for detecting aggression or to successfully conclude a conflict.

Some Organizational Background

The Air Force has responded to this new environment by reorganizing the previous 14 laboratory organizations into four "superlabs." These all reside in the Air Force Systems Command (which will be incorporated into the Air Force Materiel Command in July 1992), and are aligned with the four "product" divisions: Aeronautical Systems Division, Electronic Systems Division, Space Systems Division, and Human Systems Division.

The Human System Division (HSD) is the home of the Armstrong Laboratory (AL), the "superlab" responsible for all R&D involving the human in the Air Force environment. AL is located at Brooks Air Force Base, San Antonio, Texas and is organized into four directorates: Aerospace Medicine, Human Resources, Occupational and Environmental Health, and Crew Systems.

The Air Force Aerospace Medical Research Laboratory, later renamed the Armstrong Aerospace Medical Laboratory, is no more. The facilities and personnel at Wright-Patterson Air Force Base are now a part of the AL Crew Systems Directorate (AL/CF). The Human Engineering Division, whose name has *not* changed, is one of three technical divisions under CF and has the official symbol *CFH.*

The Human Engineering Division

The Human Engineering Division (HE) has a long and distinguished history, dating back to 1945, when it was established as the Psychology Branch of the Aero Medical Laboratory. Its founder and first Chief was Paul M. Fitts, a pioneering figure in experimental psychology research. He is credited with having organized and directed the first major Air Force effort in the field of human engineering. The Human Engineering laboratory building now bears his name, as a result of memorialization in 1985.

HE was established as a Division in 1968, and has had three Chiefs: Dr. Julien Christensen (1968-1974), Mr. Charles Bates (1974-1991), and the present Chief, Dr. Kenneth R. Boff, who assumed the leadership in April 1991.

In light of the changing world situation and the resulting overall military reorganization activities, Dr. Boff determined that HE would have to be restructured to better meet the challenge of continuing to provide the kind of high-quality human engineering R&D and field support that the Division had provided in the past. He reorganized the Division by redefining branch missions and shifting some personnel between branches.

Dr. Boff redefined the HE branch missions with three goals in mind. First, he wanted to balance the research and development sides of each branch's activities. Second, he sought to improve the quality and focus of each branch's science and technology by creating teams of scientists and engineers with complementary skills. In this way, the Division would be better able to sustain and nurture the quality of its personnel and be in a better position to attract new scientists when hiring opportunities occur. Last, he wanted to build a reputation for doing credible science, while balancing this with the needs of DoD and industry users.

To accomplish this, Dr. Boff felt that the HE Division should take advantage of its unique research capability to study human performance in complex system environments. While academic institutions are usually well equipped to study basic research problems in the area, they do not have the technical facilities to handle complex human/machine system studies, or the inclination to pursue such research, given the time pressures of the academic calendar. HE has the advantage of a much greater range of resources to apply to the problem, thus providing the opportunity to explore more complex situations. This is mainly attributable to 1) the availability of advanced simulators and other sophisticated technologies, and 2) a multi-disciplinary professional staff with extensive experience, who is not working against a "publish-or-perish" timetable.

The staff and facilities of the HE Division are organized into five branches: 1) Ergonomics Analysis, 2) Design Technology, 3) Crew Systems Integration, 4) Performance Assessment & Interface Technology, and 5) Visual Display Systems. A brief description of the branches with examples of their activities follows (see fig.).

Ergonomics Analysis Branch (CFHA)

The Ergonomics Analysis Branch acts as a portal for the flow of technical information and data to and from the Division. It processes and manages the transition of HE-developed models, data, and technology to the outside world, principally through the Crew System Ergonomics Information Analysis Center (CSERIAC), which it directs.

The Ergonomics Analysis Branch is focusing on multi-media communications as another way to promote the transfer of information. It is building a multi-media conferencing center to provide for the enhanced communication of HE products and information.

CFHA also provides analysis in the special area of nuclear, biological, and chemical (NBC) weapon threats. Through its NBC Operability Assessment Program, branch scientists were able to provide an in-depth vulnerability assessment of Air Force personnel in Operation Desert Storm for specific Iraqi chemical and biological agents, and delivery systems. This type of data is invaluable for the identification and development of NBC protective devices and procedures.

Research in the Human Engineering Division of the Armstrong Laboratory involves a diverse range of activities.

Design Technology Branch (CFHD)

The emphasis of the Design Technology Branch is in providing assistance to designers for incorporating human system information in the process and product of their design efforts. This is accomplished by converting research publications and data into a form which is truly *useful* for designers and engineers. The output of this process is a collection of principles, tools, standards, and methodologies which enable the designer to account for the needs, capabilities, and limitations of the human in a crew system environment.

CFHD scientists have been studying the crew station design process itself, to try to isolate those aspects of the activity where human factors principles could be applied for the benefit of the designer in the way he approaches his task—the human factors *of* design, if you will. Being able to visualize the effects of design alternatives early in the process has been found to be a valuable capability. As a result, a tool is presently under development which will provide the ability to visualize and prototype human factor considerations in a computer-aided design environment. It is expected to have considerable impact on the design community.

Crew Systems Integration Branch (CFHI)

There has been an increasing trend for military laboratories to get involved in more direct support of applications problems in the field. However, for the Crew Systems Integration Branch this has always been a major part of their activity. Originally CFHI was involved almost exclusively with human factors problems in bomber aircraft. Today they provide support for fighter, transport, and

Continued on page 18

helicopter aircraft, as well as ground-based crew systems.

Due partially to shrinking budgets, there has been an emphasis among military planners on modernizing electronic equipment in existing aircraft, rather than spending money on totally new systems. This retrofitting process presents a whole array of new ergonomic problems for the crew members. Good ergonomic design is a result of an integrated approach during original system design; but, when modern equipment is being retrofitted in older aircraft, it requires extra effort with human factors support to ensure an efficient, usable system. CFHI, with its flight-qualified, experienced observers, is equipped to provide such assistance.

An important additional function of CFHI is that, through its involvement with field units, it has the ability to test and transition new technology developed by the other HE branches. This is a valuable service, both for the Laboratory and the user commands.

Performance Assessment & Interface Technology Branch (CFHP)

This branch performs scientific analysis in basic human performance-related capabilities and limitation in a *system context.* That is, the human is studied as a part of a larger entity, which includes other persons, equipment, and situational variables. Included are studies in situational awareness, visual performance, and cognitive workload.

An exciting area of study is the application of advanced interface techniques such as multi-media 3-D visual and auditory displays. A related area, which is receiving a lot of press attention these days, is the use of *virtual* displays and controls, in which the operator is placed in a world where the control panel and instruments appear in space before him, and he is able to "touch" and operate the controls, even though they are not physically present. The technology has matured sufficiently to plan the inclusion of such systems in the near future. The challenge is to determine how these might best be utilized—if at all; it is not always appropriate to incorporate a new technology merely because it exists.

Visual Display Systems Branch (CFHV)

As the name implies, this branch conducts research and development to provide the human operator with improved visual capabilities. Following Operation Desert Storm's demonstration of the effectiveness of air operations in low-light/night conditions, CFHV has put special emphasis on supporting the integration of night vision technology in the HSD advanced development Helmet-Mounted Systems Technology Program. The new generation of night vision systems will fit under a pilot's visor, have an improved center of gravity, and weigh significantly less than existing equipment.

The scientists and engineers of the Visual Display Systems Branch are providing valuable support to industry through their leadership in developing aircraft windscreen testing methods and standards. Procedures have already been produced for testing such parameters as haze, angular deviation, reflections, multiple images, and others. A second important aspect of this program is relating the various windscreen parameters to actual human performance; i.e., how much is the mission affected by, for example, various levels of haze or reflections in the windscreen? It is important to know if some of the windscreen aberrations degrade pilot effectiveness more than others?

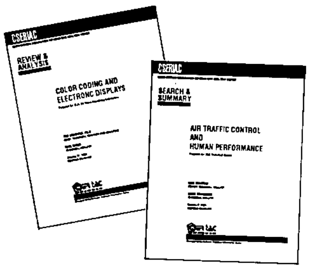
The Future

Some of the target areas to be addressed by HE scientists as they fulfill their portion of the new Armstrong Laboratory mission are 1) the human factors of manufacturing technology, 2) ergonomics of crew stations in hypersonic vehicles, 3) capitalizing on HE's experience in physical anthropology by expanding from head-scanning to full-body technology, 4) computer-supported collaborative work, and 5) using virtual reality in crew system interfaces and design facilities.

An example of the HE involvement in these new scientific thrusts is the work presently being accomplished under 5) above. The CASHE (Computer-Aided Systems Human Engineering) program is developing an interactive, data-driven, prototyping system which allows access to, and simulation of, multiple sources of human engineering data, utilizing multi-media presentation and hypertext techniques to link the various sources. Ultimately, CASHE will provide the capability for a design team to assess the human performance implications of equipment design decisions. The combined use of integrated CRTs, small group wall displays, auditory systems, and virtual display technologies will allow designers to fully visualize and experience the operational impact of the crew system design, even in its early conceptual design phase. This computer-aided systems human engineering approach will help designers and acquisition managers to efficiently access and trade off human performance data with other engineering data relevant to the design of effective human systems.

In a world without a Cold War, where defense dollars are being diverted to other purposes, the Department of Defense must make each dollar count. If it cannot buy more, then it must buy "smarter." Restructuring DoD organizations is one solution for increasing efficiency, accomplished by streamlining the management chain and eliminating duplication of effort. With the recent reorganization, the Human Engineering Division of the Armstrong Laboratory Crew System Directorate is confident it is in a better position to ensure that our men and woman in uniform will continue to be part of the most operationally efficient and technologically superior military force in the world. ●

CSERIAC TECHNICAL SUMMARY AND ANALYSIS SERVICES



What is a Technical Inquiry?

Simply stated, a technical inquiry is a request for ergonomics information. In general, ergonomics information is technical knowledge about human abilities and performance, which can be used to enhance equipment design and development.

CSERIAC 's answer to inquiries can take many forms, including customized bibliographic searches, review and analysis of research, recommendations based on analyses, and expert consultation referrals. We have grouped these into three basic categories, based on the kind and amount of ergonomics expertise applied to the problem. The three categories are Search and Summary, Review and Analysis, and Technical Area Tasks. A fixed fee has been established for the first two; Technical Area Tasks must be negotiated on an individual basis.

Search and Summary

Search and Summary consists of a literature search and a printout of relevant abstracts, which are then bound in a booklet. A professional human factors analyst reviews the abstracts and identifies the most pertinent. The human factors analyst also consults references within CSERIAC's immediately accessible resources and provides comments and/or excerpts from these references. The main purpose of this level of response is to provide a very rapid response to requests for technical information.

Review and Analysis

This level of response includes all of the above plus direct contact with subject-matter experts, a 3-to-7 page white paper synthesizing the results of the technical review, complete copies and/or excerpts from relevant documents, and names, addresses, and telephone numbers of subject-matter experts. It also includes the requisite materials for access to databases and personal contact with the subject-matter experts. The main purpose of this level of response is the in-depth synthesis of the literature with the formation of an authoritative "conclusion" or answer regarding the question posed.

Technical Area Tasks

In this category are those inquiries requiring major CSERIAC time and material expenditures, such as preparation of state-of-the-art reports (SOARs), critical reviews, technical assessments, and handbooks, organizing workshops and symposia, or exercising computer models in our technology transfer inventory. The main purpose of this level of response is an extensive customized effort directed at solving the customer's particular needs.

Previous TOPICS

- Pilot Decision-Making Under Stress
- Speech Synthesis and Recognition
- Human Tolerances to Impact
- Operator Workload Assessment: Subjective Techniques Design Guidelines for Human-Computer Interaction
- Cumulative Trauma Disorders in the Workplace
- Shift Work and Sleep Deprivation
- Human Error
- International Anthropometric Data Sources
- Color Coding and Visual Displays

Previous CUSTOMERS

- NASA
- General Motors Corporation
- AT&T Bell Laboratories
- US Army Tank-Automotive Command
- University of Illinois
- Texas Instruments Inc.
- US Consumer Product Safety Commission
- NCR Corporation
- Naval Air Warfare Center
- Ford Motor Company
- FAA Technical Center
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Liveware Survey of Human Systems Integration (HSI) Tools

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How do you know which databases and tools can to be used for the required HSI analyses during systems acquisition? Today's answer is by conducting searches, referencing many documents, and you will probably still miss some. We hope to have an answer to the problem faced recurrently by HSI focal points and their Defense contractors. Tomorrow's solution is to conduct a survey of all HSI tools, methods, and databases; place the results in an easily accessible database; and make the information available in catalogue and computer disk format. This is exactly what is planned under the Liveware Survey and Database Program. Before we explain the mechanics of the survey, let us see what got this project started.

Project Summary

Pressures to accomplish more with smaller defense forces, and widening interest and direction in Human Systems Integration have accelerated the need for comprehensive information about available HSI tools and databases. HSI studies, analyses, and plans are now required throughout the Defense acquisition process, as directed by Department of Defense (DoD) Instruction 5000.2, Defense Acquisition Management Policies and Procedures. In addition, North Atlantic Treaty Organization (NATO) countries have become interested in HSI as a means to ensure effective development/modification of defense systems. Moving to meet this NATO-wide need, the Office of the Assistant Secretary of Defense (OASD) for Force Management and Personnel (FM&P) HSI Office tasked the Defense Training and Performance Data Center (TPDC) to develop a comprehensive database of "Liveware" information. "Liveware" is the name coined to describe collectively all acquisition disciplines which directly affect humans in defense systems. Liveware domains include Manpower, Personnel, Training, Safety, Health Hazards Prevention, and Human Factors Engineering, the same disciplines involved in HSI.

To build the Liveware database, TPDC developed automated and manual survey instruments to collect essential information from HSI tool and database developers, maintainers, and users. The survey questions were approved by the NATO Research Study Group (RSG).21. CSERIAC was enlisted to assist with the survey and verification of database content. The resulting database will be available on-'' ꞓ and on disk to the government and industry acquisition communities. This database will support use of HSI tools and databases throughout the acquisition process. In addition, the database will include the results furnished by other NATO nations collected from their internal surveys. The goal is to help Defense acquisition personnel and their contractors use HSI tools, techniques, and data to develop the most cost-effective defense systems possible. By optimizing the use of and environment for people using HSI tools and databases, the goal of greater consideration of people-related issues within developing defense systems can be reached.

Background

Gaining Momentum

DoD and Government Accounting Office studies found that the weapon system acquisition process could be improved by focusing more attention on Manpower, Personnel, Training, Safety/Health Hazard Prevention (MPTS) and Human Factors Engineering (HFE) throughout acquisition. In 1986, Deputy Secretary of Defense, William Taft, tasked the OASD(FM&P) to oversee and remove systemic causes of human-centered problems in defense systems, and establish a method of ensuring continuing emphasis in this critical area of the acquisition process. Several DoD- and Service-level working groups, convened to implement this direction, realized that HSI requirements needed to be established as an integral part early in the acquisition process to influence design.

DoD Policy

The resulting policy was published in DoD Directive 5000.1, "Defense Acquisition," and DoD Instruction 5000.2, "Defense Acquisition Management Policies and Procedures" (February 1991). These directives included major sections on HSI; Systems Engineering/HFE; Integrated Logistics Support/Manpower, Personnel, and Training (MPT) elements; and System Safety. These sections emphasize that the human-machine interface must be routinely considered throughout the acquisition process. For example, the HSI section states, "Human considerations shall be effectively integrated into the design effort for defense systems to improve total system performance and reduce costs of ownership by focusing atten-

Table 1
HSI Survey Efforts

EFFORT	LIVEWARE DOMAINS COVERED							SERVICE			TOOL /TECHNOLOGIES COVERED						
Title Author(s) Corporation Sponsor Date (Related studies follow each other)	Manpower	Personnel	Training	Safety	Health Hazards	Human Factors Engineering	Logistics	Air Force	Army	Navy/Marine Corps	Non-automated	Automated	Tool	Database	MIL-STD/HDBK	REGs/Pamphlets/Guides	Facilities
Advanced Human Factors Engineering Tool Technologies. Fleger, Permenter, and Malone. Carlow Associates, Inc. U.S. ARMY Human Engineering Lab (USAHEL). 1988						F		C	F	C	C	F	F	IF INCORPORATED IN TOOL			
Integrated Decision/Engineering Aid (IDEA). Carlow International, Inc. USAHEL. 1992	C	C	C			F		C	F	C	C	F	F	IF INCORPORATED IN TOOL	IN OTHER IDEA TOOLS	REFERENCED IN OTHER IDEA TOOLS	
Analysis Of MPT(S) During Acquisition of AF Systems. Rossmeissl, Akman, Kerchner, Faucheux, Wright, Shields, and Waldrop. Hay Systems, Inc. AF Human Systems Division (AFSC). 1990	C	C	C				C	F	C			F	F	F			
AF Human Systems Integration Tools and Databases. Gentner. Aeronautical Systems Division (ASD) Manpower, Personnel, & Training Directorate (ALH). 1991	F	F	F	C	C	C	C	F			C	F	F	F	C		
Directory of Design Support Methods. Bogner, Kibbe, Laine, Hewitt. Army Research Institute, MANPRINT Office, DoD HFE Technical Group (TG). 1990	F	F	C			F	C	C	F	C	F	F	F	F	F	F	
Logistics Support Analysis Techniques Guide (AMC Pamphlet 700-4) U.S. Army Material Command (AMC) Material Readiness Support Activity. 1991	F	C	C				F	F	F	C	C	F	F			F PRIMARILY ARMY	
Survey of Manpower Personnel Software Development Tools. Bravo and Bakalarski. Dynamics Research Corporation. Computer-Aided Acquisition & Logistics Support (CALS) Human Systems Components (HSC) Committee. 1991	F	F					C	F	F	C		F	F				
Survey of CALS Training Development Software Tools. Wall and Tucker. Raytheon, Inc. CALS HSC Committee. 1990			F				C	F	F	F		F	F				
Liveware Integration in...Acquisition: Review of Canadian Organization, Tools, & Technologies. Beevis. Canadian Defense & Civil Institute of Environmental Medicine, Human Factors Division. 1991	C	C	C	C	C	F		C CANADIAN SERVICES WITH REFERENCES TO U.S. TOOLS	C	C	C	F	C		C	C	
DoD Liveware Survey Crissey and Gentner. CSERIAC and TPDC. OASD(FM&P)/R&R(TFR) HSI Office. 1992 (In progress)	F	F	F	F	F	F	C	F	F	F	F	F	.F	F	F	C	F

F = FOCUS
C = COVERED TO SOME EXTENT

tion on the capabilities and limitations of the soldier, sailor, airman, or marine." Human element objectives shall be "initially established at Milestone I...and subsequently refined and updated at successive milestone decision points." The Services are now implementing this policy through supplements to this landmark directive.

NATO RSG.21

NATO was concerned about how the human-machine interface was being addressed during weapon system acquisition. This concern led to the establishment of RSG.21, Liveware Integration in Weapon System Acquisition, by NATO Defense Research Group Panel 8, Defense Applications of Human and Bio-medical Sciences. Participant nations are Canada, France, Germany, the Netherlands, the United Kingdom, and the United States. NATO tasked RSG.21 to identify, define, describe, and document the tools, techniques, and databases that enhance the early consideration and integration of manpower, personnel, training, system safety, health hazard prevention, and HFE requirements/issues into the acquisition process. In addition, they were to evaluate findings and identify gaps and voids in technology.

HSI

In the United States, the Liveware program is called HSI at the DoD level. Implementation programs at the Service level include Army Manpower-Personnel Integration (MANPRINT), Navy Hardware-Manpower (HARDMAN), and Air Force Integrated Manpower, Personnel, And Comprehensive Training & Safety (IMPACTS). These programs attempt to ensure that Liveware issues are treated as thoroughly as hardware and software issues.

CALS Efforts

Industry and Government have joined forces in an initiative named Computer-Aided Acquisition and Logistics Support (CALS). It is an effort to improve weapon systems quality, re-

Continued on page 22

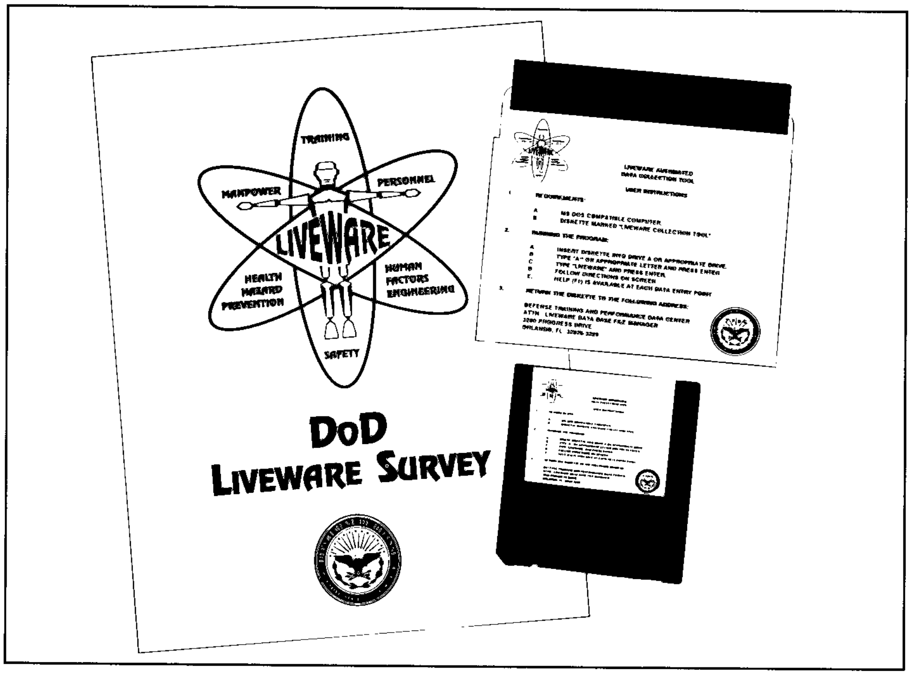

Figure 1. The Liveware Survey is available on both disk and paper.

duce development time, and decrease costs by using digital technology in the generation, access, management, maintenance, distribution, and use of technical information. The CALS strategy is to develop methods of transitioning from paper-intensive, non-integrated weapon system engineering, production, and logistic support processes to an automated and integrated operational mode. The CALS concept is to collect standardized data once, then use it many times for multiple purposes. A CALS-HSI sub-committee was formed as an integral part of this effort. One of their functions is to identify available software tools and databases for use during acquisition.

Previous HSI Tool Survey Efforts

Although several previous efforts list HSI tools and databases, none have been comprehensive of all domains or all Services. Table 1 summarizes these efforts.

NATO Study Purpose and Objectives

The purpose and objectives of RSG.21 are "(1) The identification, definition, and description of techniques, tools, databases, and data collection systems that enhance the early consideration and integration of Liveware factors to improve the operational performance and cost-effectiveness of new or modified weapon systems; (2) The documentation of all existing Liveware-integration technologies into formats suitable for practical use in accommodating profiles, report requirements, and trade-off analyses at the appropriate milestone-review points in the acquisition process; and (3) The identification and documentation of Liveware-integration technology gaps, to include a broad outline with recommended prioritization of research and development efforts designed to close those gaps."

Study Scope, Milestones, and Players

Overall Scope

The scope of the Liveware Survey is the collection and system automation of information about existing and emerging tools, techniques, and databases for all the domains which comprise Liveware. The resulting database will provide the DoD, Services, Defense Contractors, and NATO countries with access to the most complete catalog of HSI technologies. Each nation participating in RSG.21 is responsible for the solicitation, collection, and interpretation of national technologies. The data collected will be consolidated into an unclassified master database (see database benefits summarized in Table 2.).

U.S. Data Collection Methods

Data collection in the United States will take several forms. A literature search will be completed. Hardcopy survey information will be scanned for appropriate data. POCs will be identified. Contact will be made and information gathered and verified using a combination of collection tools. These include mail-out paper survey forms or an automated survey diskette (see Fig. 1), and telephone or face-to-face interviews.

Data Entry and Verification. The collected data will be entered by automated or manual means. Subject matter experts and the POC will verify using catalog format printouts during discussions with CSERIAC personnel. Data about each program will be collected from the owner/developer as well as users. The extent to which technologies are used and the type of

Table 2
Liveware Database Benefits

Liveware Database Quality	Benefits
Comprehensive	One Data Source, Rather Than Many; One Effort Used For Many Purposes
On-Line/On Diskette Access	Quick & Efficient Access, Time Saver Most Current Information
Index & Cross-References	Easy To Identify Appropriate Technology
Standardized Format	Easy to Compare & Contrast Technologies
POC & User Identification	Obtain Balanced Point of View, Detailed Information, Application Information
NATO-Wide Information	Promotes Sharing Technology, Innovative Approaches

uses are valuable in identifying the gaps and voids when establishing requirements for new technologies. Therefore, data collection will involve the entire acquisition community.

Paper Survey. The paper survey or interview requires about 20 minutes of manual entry time by a person knowledgeable about the Liveware program. The completed survey can either be mailed or telefaxed to TPDC, where it will be entered into the master database.

Automated Diskette. The most efficient collection tool is the automated diskette. The diskette comes in a package containing a User's Guide and instructions for data entry. The diskette can be used on any MS DOS-compatible computer. It contains all data entry screens; on-screen help; and easy entry, update, and retrieval commands. In addition, the diskette contains some sample data to demonstrate report capabilities. It provides a small stand-alone system which can provide an inventory of all Liveware used by an organization. A copy of the information entered on the diskette is to be mailed to TPDC for input into the master Liveware database.

Liveware Survey and Database Players and Milestones

Players

The following organizations are participating in the development of the Liveware database and data collection effort.

OASD(FM&P)/R&R(TFR)HSI, as chair of RSG.21, developed the initial requirements for the system and maintains approval authority for the database concept and collection tools.

TPDC designed and developed the prototype database and collection tools; and will develop and maintain the on-line system, input and verify the collected data, and act as project manager.

CSERIAC will support the data collection and verification, act as subject matter expert, evaluate the collection tools, and provide publicity and marketing opportunities.

Milestones

Survey and database milestones are presented in Table 3.

Table 3
Liveware Survey & Database Milestones

- ***Data Collection and Update:*** March to December 1992
- ***On-line System Development:*** March 1992 to February 1993
- ***On-Line System Available:*** March 1993
- ***First Hardcopy Catalog Available:*** March 1993

Survey Questions

The survey questions are divided into three sections: general program information, descriptive information, and owner/user information. A sample page of section 3 is presented in Fig. 2. Questions followed with blank lines require entry of words or text as appropriate. Many questions can be answered by choosing a code or multiple codes, and some narrative description is requested.

Participation Essential

For this survey to live up to its potential, all tool developers and owners must request a survey instrument, complete, and return it to TPDC. By making this information available NATO-wide, we hope to improve the consideration of human-centered issues in acquisitions and modifications. We hope the desire to meet this commendable goal will be enhanced by furnishing free publicity for tool developers. The resulting dialogue between users, developers, and maintainers should help encourage tool use, lead to improved tool design, and result in acquisitions of more cost-effective defense systems. The OASD(FM&P)/ R&R(TFR) Human Systems Integration offices encourages your participation.

SECTION 3
LIVEWARE OWNER/USER INFORMATION

3.1 OWNER/USER INFORMATION:

Point of Contact's organization or commercial firm program association: (Circle one)
O = Owner   U = User   B = Both Owner and User

Owner/User organization or commercial firm name:
____

Organization or commercial firm address:
Street:____________________
____
City: ____________________
State Code: __   ZIP:______   Country Code:__

Commercial Telephone Number:__________
Commercial Telefax Number:__________
DSN Telephone Number:__________
DSN Telefax Number:__________

Point of Contact Name:____________________
Rank or Title:__________

User work discipline: (Circle one)
M = Management   E = Engineer/Designer
S = Scientist/Researcher   T = Training Developer
C = Cost Analys: O = Other

Required days of training:____

Frequency of program use: (Circle one)
D = Daily   W = Weekly   M = Monthly   Q = Quarterly
S = Semiannually   Y = Yearly   R = As Required

Program user community sector: (Circle one)
C = Commercial   M = Military   G = Government

LIVEWARE domains applied during program use: (Circle all that apply)
M = Manpower   P = Personnel
T = Training   S = Safety
H = Health Hazard   E = Human Factors Engineering
I = Integration

Figure 2. A sample page from the survey

Where to Obtain the Survey

The survey is available in either hardcopy or automated format. To obtain it, call, write, or telefax your request to the following address/ number. Specify which collection tool format you prefer for your data entry. Submit completed forms to the same address. ●

Defense Training and Performance Data Center
ATTN: Liveware Project Manager, M. Crissey
3280 Progress Drive
Orlando, FL 32826-3229

Telephone: (407)281-3643
FAX:(407) 282-8922
E-Mail: TPDC047@TPDC.NAVY.MIL

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- organizes and conducts workshops, conferences, symposia, and short courses;
- manages the transfer of technological products between developers and users;
- performs special studies or tasks for government agencies.

Services are provided on a cost-recovery basis. An initial inquiry to determine available data can be accommodated at no charge. Special tasks require approval by the Program Manager.

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